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OPERATING 300 KV. IN QUEBEC

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INTRODUCTION

The purpose of this paper is to describe a 300 KV. Transmission system presently comprising 1300 circuit miles of transmission lines located in the Province of Quebec in Canada and to give a record of operating experience starting in October 1956. This paper is not intended to describe the economic features nor is it intended to give solutions to operating problems that exist. We believe that a record of the operation from 1956 to the present time together with the difficulties associated with such operation is of sufficient interest to promote discussion, without the paper giving any final solutions to the problems that exist.

DESCRIPTION OF THE SYSTEM

To appreciate the operating problems a brief description is essential.

The Province of Quebec, the largest province in Canada, is an ideal area for Hydro electric energy as its topography is roughly a plateau having many lakes and water storage facilities, the rivers having large drainage areas and the precipitation relatively heavy. The rivers flow from the central plateau southward to the St.Lawrence, northward to the Arctic (James & Hudson's Bay) and eastward to the Atlantic ocean. The populated areas are in the southern portion to the province mostly along the north and south shores of the St. Lawrence River.

The area in which the 300 KV. system is in operation is from Montreal north eastward along the shore of the St.Lawrence River and then some 85 miles inland to a hydraulic powerhouse which has an installed capacity of over 1,200,000 h.p. In October 1959 a second powerhouse some 40 miles downstream will be linked into the system and will require practically doubling the present 300 KV. circuits. The powerhouses mentioned are known as Bersimis #1 which has been the subject of many papers and we do not propose to describe it except as a source of energy. Sufficient to say that in Bersimis #1 powerhouse there are eight (8) generators rated 120,000 KW. each, driven by hydraulic turbines. The water travels through an eight mile tunnel with an average head 875 ft. These are Francis runners. Tests have shown that the turbines have developed over 200,000 h.p. when a minimum number of machines are in service. This obviously reduces tunnel loss and therefore the output under these conditions is above guarantee. The second plant some 40 miles downstream will have approximately one half the head and five machines of the same rating will be installed.

The generating stations are of the unit type having no low voltage switching. The bus arrangement is simple in the case of Bersimis #1, 4 units on each of two bus sections, a tie breaker, and two lines on each bus section. The relaying is impedance, 3 phase reclosing, bus differential, and full complement of generator protection. The four transmission lines leaving the powerhouse are carried on double circuit steel towers to a terminal substation near the City of Quebec, approximately 235 miles distant. At this point the transmission circuits are again bussed, onload tap changing auto-transformers and phase shifting transformers are installed for load delivered in Quebec City at 230 KV. From this substation in Quebec City only two circuits are carried to Montreal a distance of about 165 miles where onload tap changing transformers are installed and power is supplied to the 120 KV. network. The reason for the phase angle transformer at Quebec is that there existed 120 KV. tie lines prior to the 300 KV. installation and load flows over the 300 KV. and 120 KV. parallels is controlled by these phase shifting transformers of which there are three now installed each having 20 electrical degree onload tap changing quadrature phase shifting and rated 150,000 KVA.

The transmission lines lie somewhat inland from the St.Lawrence River and in certain localities pass through uninhabited regions where it was necessary to build construction roads. Throughout the transmission portion of the system particular care was taken during construction to build these circuits in a very substantial manner, the insulation level also was high (1550 B.I.L.) primarily due to the inaccessibility. Particular care was taken during the manufacture of the conductor and all stranding for the outside of the conductor was thoroughly inspected, free of burrs or marks of any kind before drawing, corona rings were installed at every insulator string and the R.I. level of these circuits is extremely low. Figure #1 shows a standard transmission tower. Where these are located on common right of way, they are spaced 200 ft. center to center. The conductor is 1,272,000 c.m. A.C.S.R. except for four miles at end of each line where the conductor is 1,590,000 c.m. A.C.S.R, There are two ground wires per tower of 7/16 inch galvanized steel. One of the interesting features is a single span crossing of these transmission circuits over the Saguenay River, length approximately 5,000 ft.

At the Montreal terminal there are six receiving transformers onload tap changing 300 KV. to 120 KV., 100 MVA. each, having a delta tertiary on which there are two banks of static capacitors each rated 18,000 KVAR.

CIRCUIT BREAKERS

The circuit breakers on the 300 KV. are all of the air blast type these having been purchased from three manufacturers. The relays for the transmission line are impedance units for fault-detection and directional-distance units using a voltage-comparison method for precise measurement. A set of relays for one line terminal consists of:-

a) One cycle, first zone, phase-to-ground fault protection.

b) Phase-to-ground and phase-to-phase protection with these zones, with the instantaneous zones operating in 6 cycles.

c) Phase overcurrent relays and ground overcurrent relays, non directional, operating through a timer, for back-up.

d) An automatic recloser designed for three phase reclosing, which allows a dead period of approximately 18 cycles.

Three-phase tripping only has been used on these lines. Interconnections between relays on each pair of lines prevent reclosing if both lines of the pair trip simultaneously at one end.

Speeding-up of the relay protection for end-zone faults is accomplished by a power-line carrier system operating over each pair of lines. Operation of any distance relay in the first zone sends a trip signal to the corresponding relay at the far end of the line; this signal permits that relay to trip with no time delay if its fault-detecting impedance elements have seen the fault. This signal bypasses the timing sequences which would otherwise be set up for clearing a second - or third - zone fault.

Operation of the recloser is permitted by the relays only when the relay has tripped the line by its own first zone measurement or by fault-detection speeded-up by a carrier signal received from the other end of the line, and when the adjoining end of the other line with which it is paired has not tripped simultaneously. Automatic reclosing is permitted when tripping is initiated by the 6 cycle relays in their first zone only.

A selector switch at each relay terminal allows a choice of several combinations of relays for use when certain components of the relay or carrier equipment are out of service. Briefly it allows a choice of: speeded-up tripping by carrier with automatic reclosing; the same without automatic reclosing; independent operation of relaying at each end of the line (no carrier); operation on overcurrent relays only, and operation on overcurrent relays at one end with speeded-tripping by carrier signal. These choices are made available to the operating engineer to control protection sequences when the carrier or any major component of relaying is out of service for test or adjustment. There have been a number of incorrect relay operations which can be explained as "growing pains". The transmission system has opened and reclosed in a satisfactory manner.

OPERATION

The system at present is operated practically flat voltage 315 KV. In initially placing the system in operation with two generators and two lines the #1 line was carrying the output of one machine, the #2 line was on build-up, using the second machine, as soon as the voltage of the second line approached the voltage of the operating line and the frequency of the build-up generator approached 60 cycles the generators locked in and we found it possible to transmit power from the line on build-up to the loaded line through the electro-static capacity of these two circuits (which were on the same tower line) of 4 or 5,000 KW. The synchroscope at the powerhouse showed the two lines 90° out of phase, Upon opening the turbine gates beyond the normal noload gate opening lock-in could be broken but it was found impossible to synchronize the machine at either the sending or receiving end as this breakaway was extremely fast and pulsations existed. The method of operation was changed and lines are now switched by simply opening or closing although the charging KVA. is over 100,000.

The power transformers are equipped with gas pressure and gas accumulation relays. Some time ago one transformer showed gas accumulation which proved inflammable. Upon inspection the trouble was located in a hot core bolt on the preventive auto-transformer. This transformer is in the tap changer circuit but is located in the main power transformer bank and had this not been located by the gas accumulation relay it could have developed into major transformer fault.

Tap Changing

The tap changing gear was designed to operate 100,000 times without maintenance. The gear was inspected after 50,000 operations and found to be in good working order. However, it was decided to filter the oil in the tap changer compartment as long as it was removed. After the filtering process the oil was pumped into the top of the tap changer compartment using standard filter hoses. During this process (the power transformer being disconnected from the line) a major explosion occurred in the tap changer compartment doing considerable damage. Further investigation showed that this oil under pressure was sprayed into the compartment and a static voltage existed. Adding a probe into the oil stream we discovered voltages of 30,000 existing. We believe that the actual explosion which occurred was set off by a static discharge produced by the sprayed oil however, the gas which actually exploded was probably inflammable gas in the tap changer compartment that had been produced due to operation and arching of the tap gear and which gas had not been purged prior to filling. The static mentioned is produced only in cold weather when humidity is low.

Potential Transformers

The Transmission system as mentioned is designed for 1550 B.I.L. This is reduced to 1200 B.I.L. near each station. The station itself has an installation B.I.L. of 1300. Potential for relays is derived from 1300 B.I.L. potential transformers; capacitor potentials are used for synchronizing. We experienced a number of failures of the potential transformers. These of course are unprotected and a failure results in a bus fault. The reason for the failure in the potential transformers is probably instability of insulation. The potential transformers are being replaced with cascade type both 4 section and 2 section, each cascade transformer will be nearly 18 ft. tall built on porcelains nearly 3 ft. in diameter. B.I.L. of the potential transformers has been increased to 1550 and the 60 cycle test also increased.

Transmission Losses

Our records, even using kilowatt hour meters, (generation input vs delivery) indicate that snow could cause losses of upwards of 60 KW. per mile. When the transmission system is very extensive (400 miles from end to end) the losses during a snow storm could be quite heavy. Our program is to install instantaneous differential kilowatt meters on one or more of the transmission lines to record graphically the losses, and to accurately report the precipitation conditions. We believe that the subject of corona losses with snow precipitation at voltages in the 300 KV. class can present a serious problem. We hope that this will be the subject of a future paper.

Dancing Conductors

Since the 300 KV. transmission system was first energized in the fall of 1956, the section between Bersimis and Quebec City has remained trouble free. However, gallopping occurred on two occasions on the double circuit line between Quebec and Montreal.

The first case took place in late February 1957 during a wind and sleet storm. At the time two generators were in service at Bersimis feeding over one line to Quebec and two lines from Quebec to Montreal. A total of five trip-puts occurred of which two involved both lines simultaneously.

The latter case took place in mid January 1959 in the early morning hours. Again there was a combination of wind and sleet storm much more severe than previously. Fourteen single line openings were registered involving manual reclosing. Lines were left out for about one hour since they could not be kept in service until the velocity of the wind decreased slightly.

It must be noted that single shot auto-reclosure feature was in service in both instances. Interruptions referred to above only account for lock-out trips.

Tower Footing Resistances

As a great portion of these long transmission lines are in mountainous and rock country and in an attempt to keep the tower footing resistance to a minimum, 4 ground wires were laid in the footing excavations before installation of the grillage or concrete footing placement. In addition counter-poise and crows-foot were laid where tower footing resistances were about 10 ohms. We have no record to date of having any lightning outages.

Radio Interferences

As mentioned previously the radio interference voltages on the 300 KV. system are very low, measurements have been taken after initial energization and compared with measurements after conductor seasoning and these measurements have shown that conductor seasoning has reduced the radio interference voltages.

Tower Lighting

The 1959 addition to this system includes a major river crossing approximately 15,000 ft. with clearances for navigation. At this particular location small islands are available and there are 5 towers in the river, the crossing which will require lighting according to aviation requirements. At all of the major river crossings the towers are slightly modified and the ground wires are raised, the steel ground wire is replaced by a standard A.C.S.R. conductor and insulated throughout the crossing and can be used for phase wires as a replacement for the one of the lower conductors. Normally the string of insulators is jumpered out at each tower. In the particular crossing mentioned we propose to remove the earthing of one of the ground wires at each tower and replace it with one or more heavy duty 4 KV. lightning arresters and energize this wire from a normal 4 KV. distribution circuit and install a distribution transformer at each tower to supply the necessary lighting. The distribution transformers will act as electro-static drain coils when the 4 KV. is de-energized during the daylight hours. The lighting arresters we expect will effectively ground the top conductor for lightening protection of the transmission system and the electro-magnetic induction will probably be insufficient to energize the distribution transformers to any great voltage.

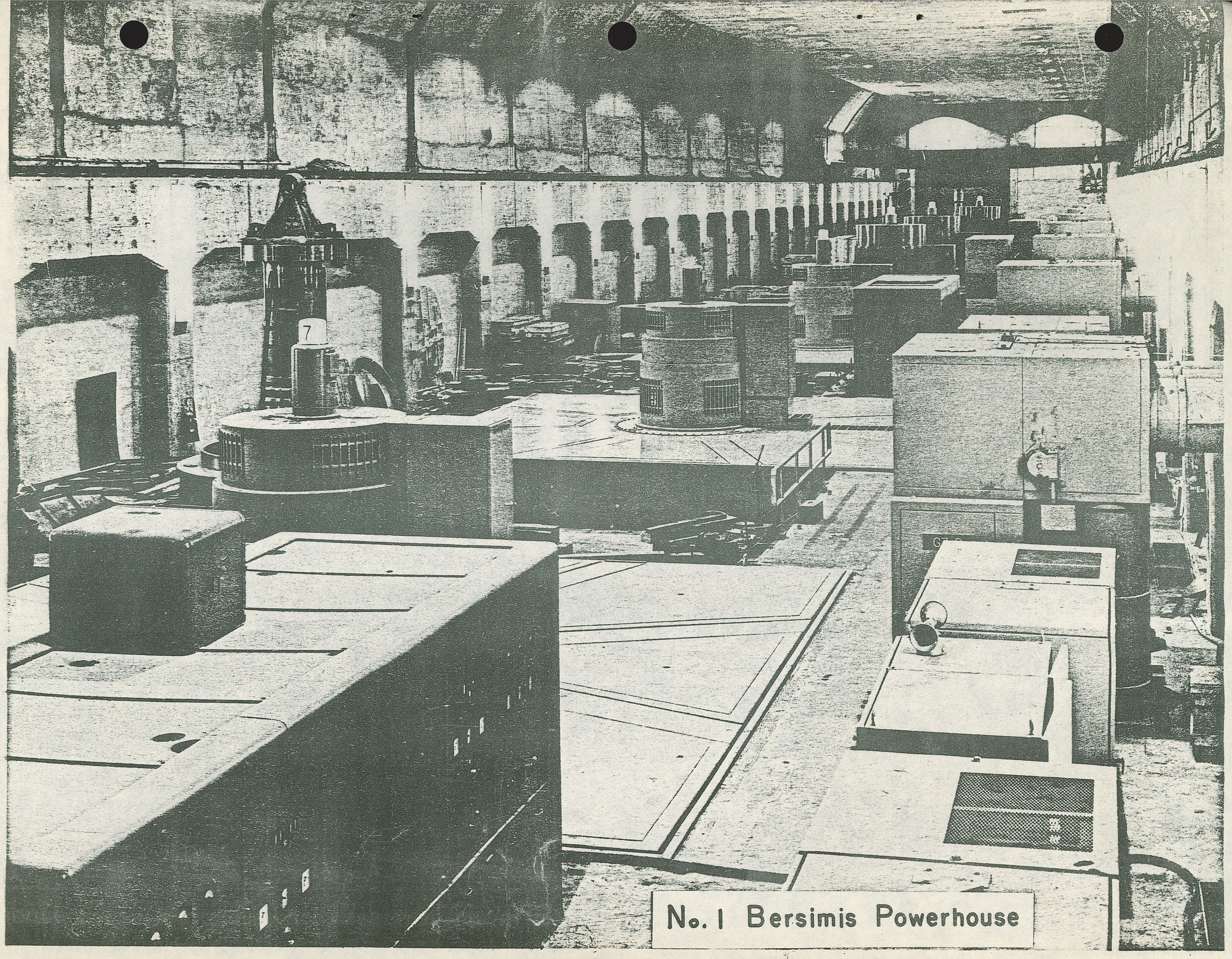
Transformers- Bout-de-L'Ile Substation

As previously mentioned at the Montreal terminal (Bout-de-L'Ile Substation) there are six receiving transformers onload tap changing, 3 phase, 3 winding with static capacitors on the 11 KV. tertiary. The initial installation consisted of 3- 18,000 KVAR banks. In November 1958, nine more 18,000 KVAR banks were installed. In late December 1958 these transformers began to show gas accumulation which proved to be inflammable in 4 out of the 6 transformers. At the present writing the actual cause has not been determined, tests are in process, the following tests had been concluded with no positive results:

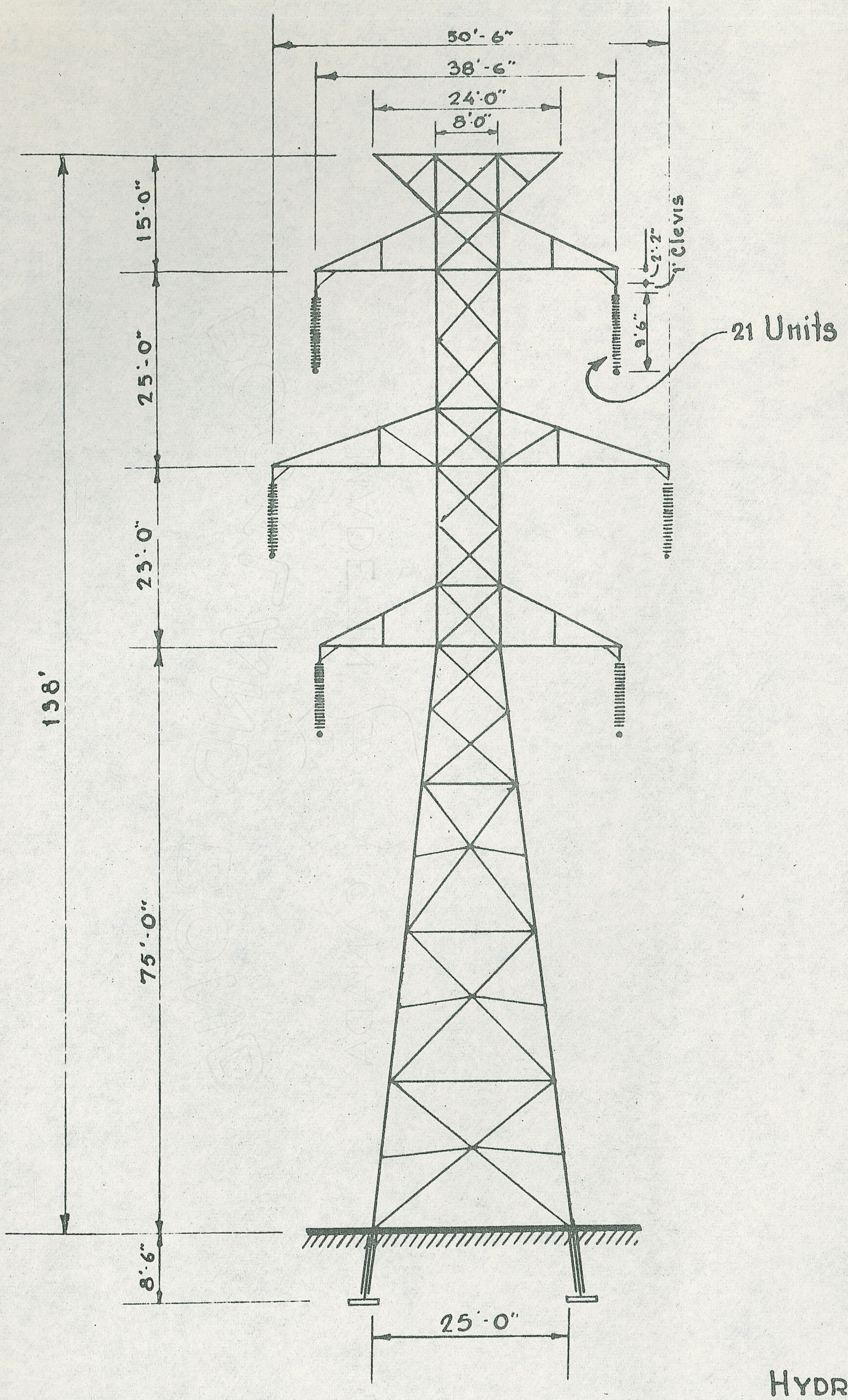
a) Resistance measurements of the tertiary windings by using a heavy current D.C. welding machine, this has eliminated the possibility of hot joints.

b) It has been determined that some of the transformers do not produce gas with the static capacitors disconnected and produce gas after the static capacitors are connected and draw current from the tertiary which has proven that the fault is definitely of the tertiary and not in the primary or secondary windings. Cathode ray and magnetic oscillograph records have been taken to determine whether capacitor switching has produced excess voltages which has destroyed tertiary insulation.

c) The tertiary winding is composed of 20 small conductors forming the conductor for the tertiary pie. There is also an aluminium electrostatic shield between the tertiary and the high voltage windings. Tests are now being conducted to energize the tertiary at some lower voltage shorting the high voltage windings and passing full current A.C. through the tertiary in an attempt to determine whether there are eddy current losses, which will produce a hot spot either in the electro-static shield or in the tertiary conductor from insulation failure of the conductor stranding which insulation failure could have been caused by high voltages produced by capacitor switching. Should time permit further details of this particular transformer fault will be reported as an appendage to this paper or verbally during presentation.



No. 1 Bersimis Powerhouse



HYDRO-QUEBEC

BERSIMIS-QUEBEC 1ST 300 K.V. LINE

STANDARD SUSPENSION